

10/550263

1

12/PRts

A DEVICE AND A METHOD FOR STABILIZING AND CONTROLLING THE
LOWERING OR RAISING OF A STRUCTURE BETWEEN THE SURFACE
AND THE BED OF THE SEA

The present invention relates to a device and a
5 method for stabilizing and controlling the lowering or
raising of a structure between the surface and the bed of
the sea, and more particularly a structure constituting a
receptacle having a leaktight compartment useful for
recovering polluting effluent from a wreck.

10 The term "structure" refers to any equipment, tool,
machine, and in particular underwater well-head elements
on oilfields, oil processing units, or even segments of
underwater pipe that are towed on the open sea from their
site of manufacture for installation on the sea bed.

15 The present invention also relates to a method and
an installation for confining and recovering effluent at
sea, and more particularly polluting effluent contained
in a sunken and damaged ship lying on the sea bed, and it
also relates to a method of putting the installation into
20 place on the sea bed.

When an oil tanker is wrecked, the ship sinks,
generally after it has been severely damaged and has
already lost part of its cargo. When the depth of water
is considerable, for example 100 meters (m) or 200 m, it
25 is generally not practical to recover or refloat the
wreck, however the hull must be completely emptied and
rinsed, or covered in an external "big top" type
structure so as to ensure that corrosion of the shipwreck
over time leading to local or generalized holes will not
30 allow the content of the ship to be released and
dispersed by currents, thereby leading to pollution that
might extend over years or even tens of years.

Numerous methods and devices have been studied and
used in the past in an attempt to recover highly
35 polluting cargoes, but they are very difficult to
implement, and the operations involved take a great deal
of time, generally leading to secondary pollution, since

recovery rates are far from satisfactory, particularly when a method needs to be implemented at great depth.

In particular, French patent No. FR 2 804 935 in the name of the Applicant describes a method of recovering
5 polluting effluent that is lighter than water and that mixes poorly or not at all with water, the effluent being contained in a tank in a sunken and/or damaged ship lying on the sea bed, that method comprising the following steps:

10 1) a receptacle having a bottom orifice is lowered with the help of positioning means to directly in the vicinity of and vertically above at least one opening in the hull and/or the tank of the ship that is putting the inside of the tank of the ship into communication with
15 the outside, so as to recover said polluting effluent directly as it flows out through said hole directly facing the receptacle, by virtue of the effluent rising into said bottom orifice of said receptacle;

20 2) when said receptacle is full of polluting effluent, it is raised using said positioning means until means for emptying said receptacle are accessible from the surface, said emptying means comprising a closable top orifice in said receptacle and/or an emptying pipe connected to said top orifice at the top of said
25 receptacle;

3) said receptacle is emptied into an installation or a ship on the surface via said emptying means accessible from the surface; and

30 4) steps 1) to 3) are repeated until the desired quantity of effluent has been recovered.

In a first variant described in FR 2 804 935:

a) said receptacle consists in a funnel-shaped bell whose open large base constitutes said bottom orifice and covers solely the zone through which said effluent is
35 leaking out, said zone being a localized zone of small area including one or more of said openings in the hull

and/or the tank of said ship, and the top small base of said funnel gives access to said top orifice;

b) said positioning means comprise:

5 • means for anchoring said receptacle to the ship, said means comprising cables connecting attachment points fixed to the circumference of said large base of the funnel to attachment points on the ship or in the vicinity thereof; and

 • tensioning means comprising:

10 • floats connected to the circumference of said open large base of said receptacle and around the tubular section in the top portion of the small base of said funnel; and

15 • winches corresponding to said attachment points on the ship or in the vicinity thereof; and

 c) said emptying means comprise a said emptying pipe connected at one end to said top orifice of said tubular section at the top of said funnel, said pipe being put under substantially vertical tension by means of a float
20 connected to the free end of said pipe.

 In that first variant, operating said positioning means during successive operations of lowering and raising said receptacle takes a very long time and is quite difficult to perform at great depth. In addition,
25 pumping through a said emptying pipe is not possible at said depth, in particular when the effluent is highly viscous and tends to freeze in the form of a paraffin. Even if a heating system were to be installed in the collection zone or in the top of the bell while rising,
30 the viscous effluent tends to freeze, thus making pumping very difficult.

 In a second variant described in FR 2 804 935, said receptacle consists in:

35 • a rigid container of substantially tubular shape which is held in a vertical position by means of floats installed at least at the top end or at both the top and bottom ends of said container; and

• said top and bottom orifices of said container are closable such that said receptacle can be raised to the surface and installed floating in a horizontal position when said orifices are closed, said receptacle then being
5 suitable for towing to an installation or a ship for storing said effluent.

Such rigid containers of a so-called "cigar" shape are large in size and difficult to lower to the sea bed, and in order to avoid successive operations, a preferred
10 implementation is described in which said container occupies the full depth of the water between the wreck and the surface. However it is clear that that second variant cannot be envisaged for depths in excess of 1000 m since that would require a receptacle that is much
15 too large, impossible to install or lower frequently.

In practice, the various implementations described in FR 2 804 935 are not suitable for acting in depths greater than 1000 m since because of the very great depth of water, the accumulated length of time for go-and-
20 return trips to depth becomes completely unacceptable given the very high cost of the intervention ships used to perform those operations.

The various devices and installations described above need to be implemented over each leakage zone from
25 the wreck, and that represents a serious difficulty in terms of operation and duration of operations since as a general rule wrecks contain numerous leakage zones and in addition, as the wreck is emptied, because that leads to deformation of the hull, new cracks generally arise thus
30 requiring substantially continuous monitoring of the wreck and correcting actions to be taken at once.

Open-based rigid receptacles have been proposed that are bell- or cap-shaped for the purpose of covering not a localized leakage zone but an entire shipwreck on the sea
35 bed in order to recover the polluting effluent escaping therefrom via a plurality of leakage zones in said wreck. Such receptacles are of large dimensions since they are

designed to cover ships of large dimensions of the oil tanker type. Putting such a structure of large dimensions into place on the sea bed raises problems of manufacture and of positioning on the sea bed under
5 conditions that are technically reliable. Such structures present a considerable amount of weight and require the use of numerous and bulky floats in order to place them on the sea bed using procedures that are complex and costly to implement since the effects of
10 currents, even if they are smaller at great depth, nevertheless remain considerable because of the immense areas of such structures.

A recovery method is also known in which said effluent is recovered using a shuttle tank including at
15 least one bottom orifice fitted with a valve that is suitable for co-operating with an emptying device secured to a tank wall, and the method comprises the following steps:

20 1) lowering said shuttle tank from the surface to the bed of the sea, causing said bottom orifice of the shuttle tank to co-operate with an emptying device on the wall, and closing the valve of the bottom orifice;

2) filling said shuttle tank until it is full of effluent;

25 3) allowing the shuttle tank to rise to the surface, said shuttle tank including buoyancy elements which enable it to rise to the surface more easily;

4) preferably storing the shuttle tank full of effluent in a surface ship, and emptying said shuttle
30 tank into said ship, or transporting it to a site where it is emptied; and

5) where appropriate, lowering said shuttle tank again or lowering another shuttle tank, and repeating steps 1 to 4 until the desired quantity of effluent is
35 recovered.

The lowering and raising of the shuttle tanks, as with any massive structure that is to be lowered to the

sea bed or raised from the sea bed to the surface, is difficult because of the mass of said structures or of said shuttle tanks. It is known to lower loads having an apparent weight in water of several hundred (metric) tonnes to the sea bed using hoist means situated on a floating support, e.g. a crane; but when the depth becomes considerable, the use of conventional steel cables is problematic since, in addition to the load of said structure, it must also support its own weight, and that can represent up to 50% of said load capacity for a depth of 3000 m. Synthetic cables can also be used that do not present that drawback, but their cost is very high and their use with winches or capstans presents extreme difficulties for heavy loads and depths of 1000 m to 4000 m, or even greater.

Thus, it is generally sought to reduce the apparent weight in water of such loads by creating buoyancy. But, the mass of said loads is thus increased by the mass of said buoyancy elements, and by the "added mass" of water, i.e. the mass of water adjacent to the load that is entrained upwards or downwards during vertical movements, and this can represent an overall inertial mass of 400 tonnes or 500 tonnes for a load mass of 100 tonnes.

The cable connecting the load to the floating support is tensioned in a vertical straight line, and since said floating support is subjected to swell, said cable is subjected to rolling and pitching which requires the use of winches having controlled tension, or the use of hydraulic devices known as pounding compensators, which prevent said cable from rupturing by limiting the tension in said cable to an acceptable value. Such equipment is technically complicated and very costly, especially for heavy loads or for depths of 2000 m to 3000 m, or even 4000 m or greater.

The object of the present invention is to provide a device and a method for controlling and facilitating the lowering and raising of a structure that is heavy, and

possibly bulky, such as the above-mentioned receptacles or shuttle tanks for recovering effluent. However, the invention is also applicable to any other type of structure, and it is even applicable to stabilizing such a structure between the surface and the bed of the sea, particularly at great depth...

Another object of the present invention is to provide a method and an installation making it possible to confine and recover the content of the hold and/or tanks of a ship, e.g. an oil tanker, resting on the sea bed in great depths, e.g. greater than 3000 m or even 4000 m to 5000 m, while avoiding the drawbacks of prior art methods and devices, and in particular being easy and simple to implement in spite of being of very large dimensions.

Another object of the present invention is to provide a method and an installation making it possible to confine and recover polluting effluent from a vessel that has sunk, particularly in great depth, by means of an open-based rigid receptacle in the form of a cap that completely covers the shipwreck so as to channel all of the effluent escaping therefrom into a single volume, and so as to organize raising the polluting effluent to the surface from said receptacle at the sea bed under the best possible conditions.

A more particular object of the present invention is thus to provide an open-based receptacle of cap-shape suitable for completely covering a wreck on the sea bed and for recovering polluting effluent escaping therefrom, and which is technically reliable and capable of being implemented on the sea bed using a method that is simple and technically reliable.

To do this, the present invention provides a device for stabilizing or controlling the lowering or raising of a structure between the surface and the bed of the sea, said device being characterized in that it includes at

least one connection element of the cable or chain type, having:

• a first end that is connected to a winch on board a floating support or surface ship, and on which winch it is wound; and

• a second end that is connected to a fastener element on said structure, or on at least a first buoyancy element connected to said structure; and

• the length of said connection element is such that said winch is suitable for winding or unwinding said first end of said connection element, so that a bottom portion of said connection element can hang beneath said fastener element, i.e. beneath the fastener point for fastening said second end to said fastener element.

Where appropriate, said structure is therefore suspended from one or a plurality of said first buoyancy elements disposed thereabove. Said structure can also include second buoyancy elements integrated or incorporated inside said structure, i.e. said second buoyancy elements do not displace a volume of water that is additional to the volume of water displaced by said structure.

The term "buoyancy element" refers to an element that presents a dead weight that is lighter than sea water, and that thus makes it possible to increase the overall buoyancy that it forms together with the structure to which it is connected or in which it is integrated.

The term "to increase the buoyancy" of an element when it is immersed refers to increasing the ratio ω between the buoyancy thrust exerted on said element and its dead weight out of water. Thus, if said ratio is $\omega < 1$, the element has negative buoyancy, so it tends to sink, if $\omega = 1$, said element is in equilibrium, and if $\omega > 1$ said element floats and its buoyancy increases as ω increases.

The buoyancy of the structure can be made positive so as to make it easier for said structure to rise. For

"positive buoyancy", said buoyancy elements compensate the weight of said structure, so that the buoyancy thrust that is applied both to said structure and to said buoyancy elements is not less than the dead weight of said structure and said buoyancy elements taken together, also including, in particular, one or more connection-element bottom portions, with the resultant of the forces being directed upwards for positive buoyancy.

It should be understood that the device of the invention makes it possible to vary the length and therefore the weight of said bottom portion of the connection element hanging beneath said fastener element on said structure and supported by said structure.

For a massive structure, the stabilizing and control device of the invention includes at least two of said connection elements and said structure includes a plurality of said fastener elements, and said connection elements and said fastener elements are preferably disposed symmetrically, respectively around and on the periphery of said structure.

More precisely, the present invention also provides a method of lowering, raising, or stabilizing a structure between the surface and the bed of the sea by means of a device, said method comprising the following steps:

unwinding or winding each connection element at its first end by means of a said winch; and controlling the lowering and raising of each connection element by regulating the speed at which each connection element is respectively wound off or on said winch, so as to adjust the length of said bottom portion of said connection element hanging beneath said fastener element on said structure or said first buoyancy element and supported by said fastener element, the lowering, raising, or stabilizing of said structure being obtained when the sum of the weight of the fraction of said bottom portion(s) of the connection element(s) between firstly said fastener point(s) for fastening to said fastener

element(s) or said first buoyancy element on said structure, and secondly the lowest point of said bottom portion(s), plus the weight of said structure as a whole and of said first buoyancy element(s), is respectively
5 greater than, less than, or equal to the buoyancy thrust that is exerted on said structure and on said first buoyancy element(s) (i.e. the weight of the total volume of water displaced).

In an embodiment, the stabilizing and control device
10 of the present invention includes a said connection element constituted by a cable having a bottom portion that comprises weighting blocks disposed in a string on a said cable, said weighting blocks preferably being metal blocks secured to said cable by clamping.

15 In a preferred embodiment, said blocks present a shape such that when said bottom portion hanging beneath said fastener elements curves, two of said blocks disposed side by side are capable of coming into abutment against each other, thereby limiting the curvature of
20 said cable.

More particularly, the curvature of said cable is limited so that the minimum radius of curvature of said cables at said bottom portion enables a minimum distance to be maintained between said cable and said structure
25 that is sufficient to prevent any mechanical contact between them while said structure is being lowered or raised.

Still more particularly and advantageously, each of said blocks presents a cylindrical central portion
30 between two frustoconical ends having axes (i.e. the axes of said cylinder and of the two frustoconical ends covering its end faces) that correspond to the direction of said cable when said cable is disposed linearly, two adjacent blocks being in contact at said frustoconical
35 ends along a generator line of said frustoconical ends in the curved parts of said bottom portion.

In another embodiment, said connection element comprises a chain having a bottom portion that comprises links that are heavier than the links of the rest of the chain, and that are preferably larger so as to limit any curvature of the chain.

Where appropriate, said first buoyancy elements are advantageously disposed above said structure, with said structure being suspended therefrom, and where appropriate, said second buoyancy elements are integrated in the top of said structure, preferably integrated above said fastener elements so that the center of gravity of said structure together with said first buoyancy elements is situated below the center of thrust that is exerted both on said structure and on said first buoyancy elements, so as to provide overall stability during the entire installation stage.

The term "center of thrust" refers to the point at which the resultant of the buoyancy thrust is exerted. (The center of thrust is the center of gravity of the volume of water displaced by said structure).

As mentioned above, said heavy structure can be constituted by any load, in particular a heavy load, module, tool, or base as described in unpublished European patent application No. 0435802.6 in the name of the Applicant, that is to be immobilized in the vicinity of the sea bed or anchored on a wall or an element lying on the sea bed.

Preferably, said structure is a rigid structure of steel, other metal, or composite synthetic material containing at least one and preferably a plurality of buoyancy compartments that are preferably leaktight and that are suitable for receiving a fluid that is lighter than sea water so as to form a said buoyancy element, said compartments each being fitted with at least one filling orifice and preferably with at least one emptying orifice, said preferably leaktight compartments preferably being distributed symmetrically in said walls.

In a particularly advantageous embodiment, said structure is a massive structure constituted by an open-based receptacle in the form of a cap, the receptacle comprising a peripheral side wall surmounted by a roof wall and being suitable for completely covering a wreck of a ship on the sea bed in order to recover polluting effluent escaping therefrom, said receptacle having at least one emptying orifice for discharging said effluent contained in the inside volume of said receptacle; said emptying orifice preferably being situated in the roof of the receptacle.

The preferably leaktight compartments are designed to be filled completely or in part with a fluid that is lighter than sea water, and they thus constitute compartments that provide buoyancy to the structure constituting the receptacle, thereby enabling it to be towed at the surface and then to be lowered to the sea bed while it is being put into place, under conditions that are technically reliable and simple to implement, as explained below.

Concerning the distribution of the compartments in the walls, the term "symmetrically" means that the compartments are disposed symmetrically about one or more midplanes of symmetry of said receptacle, thus making it possible as explained below to facilitate balancing and positioning the open base of said receptacle in a manner that is substantially horizontal.

In general, said receptacle presents a longitudinal axis of symmetry like that of the ships it is designed to cover, and said receptacle presents a vertical longitudinal axial plane of symmetry when the open base of the receptacle is in the horizontal position, and more particularly, said receptacle also presents a second vertical plane of symmetry that extends transversely.

In known manner, the walls constituting said roof flare so as to define a narrow top space. Similarly, the side wall which forms a peripheral skirt of the cap is

also preferably inclined so as to form a flared funnel defining at its bottom the open base of said receptacle and encouraging effluent escaping from the wreck to rise and accumulate under the roof of the receptacle.

5 In an advantageous embodiment, the receptacle is in the form of an upside-down hull with a longitudinal axial plane and with lateral roof walls constituted by contiguous plane walls of different inclinations, thus defining flat sloping surfaces of the hull.

10 In a more particular embodiment, the receptacle presents a vertical and longitudinal axial plane of symmetry XOZ, and it comprises:

- a roof wall comprising two longitudinally extending side walls that are inclined relative to said vertical axial plane of symmetry of said receptacle so as to form an upside-down V-shape in cross-section YOZ; and

- a side wall comprising:
 - two longitudinally extending side walls that are vertical or inclined relative to said vertical axial plane of symmetry XOZ, each being contiguous with one of said longitudinally extending roof walls; and

- two transverse end walls that are vertical or inclined, preferably symmetrically about a vertical transverse plane of symmetry YOZ.

25 In an advantageous embodiment, said receptacle is constituted as an upside-down double-walled ship hull comprising a rigid structure of steel, other metal, preferably a light metal such as aluminum or titanium, or composite synthetic material, said leaktight compartments being defined by spaces between said double walls and by structural elements interconnecting the double walls.

30 The term "double-walled" is used herein to mean a wall constituted by an inner wall and an outer wall spaced apart by structural elements of the beam type forming framing that unites said inner and outer walls, themselves being made of rigid or semirigid material, specifically steel, some other metal, preferably a light

metal such as aluminum or titanium, or a composite synthetic material, for example glass fibers embedded in a matrix of epoxy or polyester resin type.

5 In this embodiment, the compartments are thus formed by the inner and outer walls of said double walls together with transverse or longitudinal structural elements interposed between the double walls and uniting them.

10 In another variant embodiment of the invention, the rigid structure of the walls constituting said receptacle is constituted by steel or metal beams assembled to one another and having leaktight compartments incorporated between them, said structure being covered on at least one face, preferably the outer face, by leakproof
15 diaphragms or webs, for example made of reinforced cloth covered in a thermoplastic material, and fixed to said rigid structure in leaktight manner. In this embodiment, said leaktight compartments are constituted by a self-contained closed casing incorporated inside said
20 structure and secured thereto.

Also advantageously, the rigid structure of the walls of the receptacle is made of concrete, preferably lightened concrete, preferably lightened by hollow expanded clay beads, within which concrete hollow volumes
25 are provided for defining said leaktight compartments.

In a preferred embodiment, the receptacle has posts, preferably regularly distributed around its periphery, with at least some of them preferably being retractable, said posts being suitable for supporting said receptacle
30 in quasi-isostatic manner when it is standing on the sea bed via said posts, the posts being deployed where necessary, and with the open base of said receptacle preferably being in a substantially horizontal position. The lengths of said posts, as deployed, where appropriate,
35 possibly differing from one another so as to enable said open base of the receptacle to be maintained in a substantially horizontal position.

In order to make it easier to put the receptacle of the invention into place on the sea bed, the walls of said receptacle are fitted on the outside:

- with second fastener elements enabling cables or chains to be secured thereto for lowering said receptacle from the surface, and for putting it into place and anchoring it to the sea bed; and

- preferably with thrusters, more preferably steerable thrusters enabling the receptacle to be moved in a horizontal direction in order to be positioned over said wreck.

Said second fastening elements may also be used for fastening additional floats to the receptacle.

The present invention also provides a method of putting a structure, and in particular a receptacle of the invention, into place in order to cover a shipwreck on the sea bed and recover polluting effluent escaping therefrom, the method being characterized in that it comprises the following steps:

- 1) filling said leaktight compartments completely or partially with a fluid, preferably a fluid that is lighter than sea water, with the extent to which said leaktight compartments are filled being adjusted so as to cause said structure, and in particular said receptacle, to occupy an equilibrium position when immersed close to the surface, in particular several meters therefrom, e.g. 10 meters therefrom; and

- 2) lowering said structure, and in particular said receptacle, to its desired immersed position close to the sea bed over the wreck by controlling lowering by means of a device for stabilizing or controlling the lowering or raising of a structure of the invention, in particular by means of a plurality of cables preferably unwound from winches on board surface ships, said cables being connected to lengths of heavy chain, the chains themselves being connected at their opposite ends to said fastener elements secured to said structure, and

preferably being distributed symmetrically around the periphery of said structure, the weights of the lengths of chain hanging beneath the fastening points on said fastening elements enabling said structure to be lowered, and the lengths of said chains hanging beneath said fastening points of the fastening elements being adapted by winding said cables out or in, preferably around said winches so as to regulate the rate of descent of the receptacle and so as to ensure that the base of said structure, and in particular the open base of the receptacle, is maintained in substantially horizontal equilibrium throughout the descent;

3) once said structure is in place in its desired position, in particular when said receptacle is in position on the sea bed so as to cover said wreck, emptying said leaktight compartments filled with fluid lighter than sea water, and simultaneously filling said leaktight compartments with sea water.

Before and/or after step 1), but before above step 2), it is possible to use ships to tow said structure, and in particular said receptacle, while it is floating at the surface, said leaktight compartments being filled with air and the receptacle floating with neutral buoyancy level with the surface or with said leaktight compartments being completely filled with a fluid that is lighter than sea water.

At above step 1), it will be understood that the filling of said leaktight compartments with a fluid that is lighter than sea water is performed in the various compartments as a function of how they are distributed in the walls of the receptacle, so that the open base of the receptacle remains substantially horizontal and so that the center of buoyancy of the receptacle remains substantially above the center of gravity of the receptacle. This applies to selecting which compartments to fill and also the rates at which they are filled.

Advantageously, in step 1), additional buoyancy is applied to said receptacle using additional floats by means of said first buoyancy elements connected to said structure, and in particular to said receptacle, and in
5 step 3), once said structure is in the desired position, said additional floats are released.

Also advantageously, after step 1) and before step 2), once said structure, and in particular said receptacle, has reached the desired position in the
10 vicinity of the wreck, overlying it, the lengths of said heavy chains hanging beneath said fastening elements and supported by the structure are reduced so as to stabilize said structure in suspension, and said receptacle is anchored to the sea bed, and then said heavy chains are
15 fully lowered so that their entire weight contributes to stabilizing said structure, and in particular said receptacle, on the sea bed.

The heavy chains may be recovered by being disconnected from the receptacle, but as explained below,
20 in order to increase the stability of said structure, and in particular of said receptacle, said heavy chains may have both ends connected to said fastening elements on said structure, or more simply the free ends of said heavy chains may be laid over the roof of said structure,
25 and in particular of said receptacle, while still connected to the cables themselves connected to the surface ships, and then the cables connected to the surface ships are separated from said chains.

Preferably, said receptacle includes posts, at least
30 some of which are preferably retractable, and said retractable posts, if any, are deployed, in such a manner that said receptacle rests on the sea bed on each of said posts in quasi-isostatic manner, and preferably with the open base of said receptacle in a substantially
35 horizontal position.

Advantageously, in the method of the invention, the receptacle is positioned on the axis above the wreck by

actuating thrusters mounted outside the receptacle and preferably distributed symmetrically about its periphery.

The fluid lighter than sea water filling said leaktight compartment may be gas oil, oil, fresh water, or a liquefied gas that is lighter than sea water such as propane, butane, or ammonia, said gas remaining in the liquid state at the temperature of sea water (2°C to 20°C) providing the pressure exceeds a few bars.

Still more particularly, in a method of the invention, in step 1), said leaktight compartments are filled with a first fluid that is lighter than sea water; and in step 2), said structure is lowered to a depth of 30 m to 60 m corresponding to a pressure of 3 bars to 6 bars, at which depth a liquefied gas that is lighter than sea water is injected under pressure into said leaktight compartments from a gas tanker ship on the surface.

Using liquefied gas as the fluid lighter than sea water makes it possible to obtain fluids presenting relative density in the liquid state lying in the range 0.55 to 0.7, thus giving two to three times more buoyancy than gas oil ($d=0.85$), and thus making it possible to use leaktight compartments of considerably smaller volume. In addition, in the event of an accident occurring such substances are much less polluting than gas oil or other oil, since they disperse naturally on reaching the surface.

Still in order to make it easier to lower the receptacle and avoid having to use leaktight compartments of excessive volume, it is advantageous in the method of the invention for installing the receptacle to fill a portion of the inside volume of said receptacle as defined on top by the roof of said receptacle and at the bottom by a diaphragm or web tensioned between said side walls of said receptacle, using a fluid that is lighter than sea water, preferably fresh water, thereby providing additional buoyancy while the receptacle is being towed at the surface, and once said receptacle is close to the

sea bed, said diaphragm or web is removed and the receptacle is placed over the wreck on the sea bed, preferably by means of said posts, as deployed, where appropriate, and then said fluid that is lighter than sea water is emptied from the inside of said receptacle via said top emptying orifice.

Finally, the present invention also provides a method of recovering polluting effluent that is lighter than sea water, as contained in the tanks of a shipwreck lying on the sea bed, in which method:

1) a receptacle is put into place in accordance with a method of the invention for stabilizing and controlling descent; and

2) the effluent recovered inside said receptacle is collected by being emptied out through said top emptying orifice.

In order to recover effluent escaping through said top emptying orifice, it is possible to use a pipe connected to a surface ship or recovery devices of the kind described in French patent No. FR 2 804 935 in the name of the Applicant, or indeed to use shuttle tanks as described in as yet unpublished European patent application No. 03/358003.6 in the name of the Applicant.

More particularly, step 2) of the above-mentioned method of recovering effluent comprises the following steps:

- lowering an empty said shuttle tank;
- positioning said shuttle tank over said receptacle in such a manner that its open bottom orifice is just above said emptying orifice of said receptacle;
- preferably securing said shuttle tank to said receptacle;
- emptying the effluent contained in said shuttle tank; and
- once full, detaching said tank from said receptacle, and raising said tank full of effluent to the surface.

Other characteristics and advantages of the present invention appear better on reading the following description given in illustrative and non-limiting manner with reference to the accompanying drawings, in which:

5 • Figure 1 is a side view in section of a receptacle referred to herein as a "sarcophagus" while it is being lowered towards a wreck;

 • Figure 2 is a side view in section of a rigid receptacle resting on the sea bed and completely covering
10 the wreck;

 • Figure 3 is a cutaway perspective view showing the structure of the sarcophagus;

 • Figure 4 is a side view in section of the sarcophagus as it is being lowered, showing how lowering
15 is controlled with the help of heavy chains;

 • Figures 4a and 4b show details of how said heavy chains can be implemented in varying manner;

 • Figure 5 is a side view in section of the sarcophagus while it is being lowered, with its buoyancy
20 being produced by gas oil in leaktight compartments integrated in its walls, in combination with fresh water inside the internal volume of the sarcophagus-receptacle;

 • Figure 6 is a side view in section of the sarcophagus, showing details of orifices for filling and
25 discharging buoyancy fluids to and from the insides of the leaktight compartments, and for removing effluent contained inside the receptacle;

 • Figure 7 is a side view in section of a sarcophagus made up of a rigid load-carrying structure
30 made of metal beams associated with buoyancy tanks filled with a low-density fluid integrated between the beams and closed by leakproof diaphragm webs on the outside face of the structure;

 • Figure 8 is a side view in section of a
35 sarcophagus made out of lightweight concrete, having internal volumes forming leaktight compartments filled with a low-density fluid for providing buoyancy;

• Figures 9a and 9b are side views in section of a sarcophagus respectively while it is being towed, its buoyancy compartments being filled with sea water (Figure 9a), and vertically above the wreck during the stage in which said buoyancy compartments are filled with a low-density liquefied gas (Figure 9b);

• Figure 10 shows a said receptacle fitted with posts on which it stands on the sea bed;

• Figure 11a is a side view of a shuttle tank that is stabilized, while rising, by a connection cable that is weighted by blocks secured to said cable and also serving to limit curvature;

• Figures 11b and 11c show states similar to those in Figure 11a, with the shuttle tank being in the rising stage in Figure 11b and in the lowering stage in Figure 11c;

Figure 11d shows a detail of two blocks 31 in contact with each other, when said connection cable is curved;

• Figure 12 shows a shuttle tank co-operating with the top wall of a structure of the sarcophagus type, for recovering therefrom, the oil flowing from a ship that has sunk and that is confined beneath the sarcophagus; and

• Figure 13 shows an anchoring and drilling device controlled by a stabilizing chain of the invention and by buoyancy elements.

Figure 1 shows the hull of a wreck or a wall of a tank 6 lying on the sea bed 7 and filled with hydrocarbon 8 of density lower than that of sea water. Said hydrocarbon is confined in the top portion of the tank or the wreck 6, its bottom portion being filled with sea water. The ship 6 generally possesses multiple openings that are hermetically closed at deck level, and leakage might occur whenever the sealing becomes damaged because of the hull becoming deformed or breaking while the ship was being wrecked.

A rigid receptacle 1 referred to herein as a "sarcophagus" constituted by a rigid structure is lowered from the surface under the control of cables 12 connected to dynamically-positioned ships 20 on the surface, as shown in Figures 1 and 2.

The receptacle 1 shown in Figures 1 to 3 has a vertical and longitudinal axial plane of symmetry XOZ and comprises:

- a roof wall (3, 3a, 3b) comprising two longitudinally extending side walls (3a, 3b) that are inclined relative to said vertical axial plane of symmetry of said receptacle so as to form an upside-down V-shape in cross-section YOZ; and
- a side wall 2 comprising:
 - two longitudinally extending side walls (2a, 2b) that are vertical or inclined relative to said vertical axial plane of symmetry XOZ, each being contiguous with one of said longitudinally extending roof walls (3a, 3b); and
 - two transverse end walls (2₁) that are vertical or inclined, preferably symmetrically about a vertical transverse plane of symmetry YOZ.

As shown in detail in Figure 3, the sarcophagus 1 is constituted by an upside-down hull shape, said hull being leaktight and double-walled, thus constituting leaktight compartments 4, preferably a multitude of leaktight compartments in continuity one with another. The structure is constituted by transverse framing members 4₃ that may be perforated or solid within a given leaktight compartment, and associated with perforated or solid framing members extending longitudinally 4₆. In Figure 3, there can be seen in an exploded cross-section corresponding to the plane YOZ, a right-hand half of the double wall 3b of the roof which is plane and inclined relative to the horizontal, e.g. at 10° to 20°, but which could be horizontal, and when it is inclined, it co-operates with the other double-walled half of the roof 3b

to form a roof with an upside-down V-shape. Each longitudinal roof wall 3a, 3b is connected via its bottom edge to a plane double-walled side wall 2a, 2b which is vertical or inclined relative to the vertical, in particular at an angle of 5° to 20° , and preferably at an angle that is smaller than the angle of said inclined longitudinally extending roof walls. The two ends of the sarcophagus 1 in the longitudinal direction XX' are closed by end double walls 2, 2a, 2₁ that provide a connection between the end edges of the side double walls 2a, 2b and the ceiling double walls 3, 3a, 3b, with said end side walls 2₁ being perpendicular to the longitudinal axis XX'. The bottom is entirely free so as to enable the sarcophagus to act like a bell to cover the wreck 6 that is to be confined.

The volumes inside the various double walls 2₁, 2, 2a, 2b and 3, 3a, 3b are defined by the inner and outer walls and by the solid framing members 4₃, 4₆ that form compartments which are leaktight relative to the outside, thus enabling them to be filled with a fluid of density lower than that of sea water, said fluid then acting as buoyancy material and compensating the dead weight of the rigid structure constituting the sarcophagus receptacle 1.

Said hull constituting the sarcophagus is advantageously built dry in an open basin, and then the leaktight compartments 4 within the double walls 2₁, 2, 2a, 2b and 3, 3a, 3b are closed off in leaktight manner. After the open basin has been flooded, the sarcophagus 1 floats, projecting well above water level because said compartments 4 are filled with air. If there is any risk of instability at this stage, it is advantageous to add ballast temporarily to the bottom thereof.

The sarcophagus 1 is then towed to deep water where all of the compartments 4 constituting the buoyancy volumes are filled with the buoyancy fluid, for example gas oil of relative density close to 0.85. The buoyancy volume is advantageously adjusted so that the sarcophagus

is in neutral equilibrium in water, with overall equilibrium optionally being provided by means of additional floats 19 capable of withstanding deep sea pressures, i.e. about 350 bars for a depth of 3500 m.

5 Said additional floats 19 may be made of syntactic foam, i.e. microspheres of glass held captive in a binder of the polyurethane or epoxy resin type, but they are advantageously constituted by a rigid or flexible casing filled with liquefied gas, e.g. butane or propane, as
10 explained below.

The sarcophagus 1 is then towed to the site, and once in position, at least two and preferably four ships 20 are connected to the ends of the sarcophagus 1 as follows.

15 Each ship 20 has a winch 12₁ provided with a cable 12, preferably a steel cable, of length that is greater than the depth of the water, e.g. 130% of said water depth. The end of said cable 12 is connected to a length of heavy chain 13, e.g. 100 m of chain having a diameter of
20 6 inches ("), the end of said chain being connected to a reinforced beam 10 constituting a fastener element secured to the structure and projecting out from the sarcophagus 1, as can be seen in Figures 1, 4, 5, and 8.

The heavy chains 13 have a self-regulating effect as
25 the sarcophagus is being lowered towards the sea bed 7, and their operation is explained with reference to Figures 4, 4a, and 4b.

In Figure 4, the cable 12 is in an intermediate position and forms a catenary type curve, with a portion
30 of the weight of the chain 13 (F) being supported by the sarcophagus while the remainder of the weight of the catenary is supported via the cable 12 directly by the ship 20 on the surface. Thus, the sarcophagus is maintained in neutral equilibrium under the effect of
35 this force F.

When the winch 12₁ on the surface ship 20 winds in the cable 12, it raises the chain 13 as shown in

Figure 4a, thereby reducing the weight of chain that is carried by the receptacle to a weight F_{\min} , since the entire weight of the chain is then supported by the surface ship 20: the sarcophagus 1 then presents an
 5 apparent weight in water that is smaller and it rises in order to come closer to an equilibrium position as shown in Figure 4 and stabilized in that position.

Conversely, when the winch 12_1 on the surface ship 20 unwinds cable 12, it lowers the chain 13 as shown in
 10 Figure 4b, thus having the effect of increasing the weight carried by the receptacle up to a weight F_{\max} . The apparent weight of the sarcophagus 1 in water is then increased and it sinks in order to approach the equilibrium position shown in Figure 4 and be stabilized
 15 therein.

Thus, under all circumstances, the configuration of the chains 13 as catenaries produces a self-regulating effect on the position of the sarcophagus while it is being lowered. Nevertheless, it is still appropriate to
 20 synchronize the unwinding of the cables 12 from all of the winches 12_1 involved in the maneuver in a manner that is very accurate so as to ensure that the sarcophagus 1 is lowered while remaining substantially horizontal. In addition, the ship 20 must remain at a substantially
 25 constant distance from the axis of the receptacle, and preferably the two ships 20a and 20b connected to opposite fastener elements 10 (Figure 1) should be situated in substantially the same vertical plane as includes the points where the chains 13 are attached to
 30 the beams 10 of the sarcophagus 1, which means that it is advantageous for the ships to make use of dynamic positioning techniques relying on a radiolocating system of the GPS type (global positioning system).

The sarcophagus 1 is preferably lowered continuously
 35 down to a distance where it is close to the wreck 6, for example 50 m from the sea bed. The sarcophagus is then positioned relative to the axis of the wreck 6 and is

oriented in the proper direction by moving the ships 20 on the surface. Said movements of the ships 20 produce an effect that is delayed by several minutes to several tens of minutes on corresponding movements of the sarcophagus situated several thousand meters below. In order to facilitate this operation, it is advantageous to install steerable thrusters 16, preferably at the ends of the structure, and more particularly at the four corners of the roof, said thrusters 16 being powered by an umbilical cord 16₁ delivering power and control signals and connected to a surface ship 20.

In the variant shown in Figures 1 and 2, winches 14₁ are installed on the side peripheral walls of the sarcophagus, and once said sarcophagus 1 is close to the wreck, an automatic underwater remotely operated vehicle (ROV) 22 controlled from the surface connects the cables 14 of said winches 14₁ to anchor points 15₁, 15₂ that have been previously installed in the vicinity of the wreck, e.g. constituted by suction anchors 15₁ or by deadweight blocks 15₂.

Once the sarcophagus has been put finally into place, the heavy chains rest on the sea bed 7 as shown in Figure 2, and the additional floats 19 are detached by means of the ROV 22, with these floats then rising freely to the surface where they are recovered. Care is taken to ensure that each of them is fitted with an acoustic beacon, thus enabling their upward travel to be followed by means of sonars on board the ship 20, and consequently making it possible to move the ships so as to avoid any collision when the floats surface. The sarcophagus 1 is then stable on the sea bed, but its stability can be further improved by recovering its buoyancy material, e.g. gas oil, as shown in Figure 2. For this purpose, a ROV 22 is used under control from the surface to connect a preferably flexible pipe 23, preferably having an S-shaped configuration, to an orifice that is provided with an isolating valve 4₄ and situated in the top of the

compartment 4, with care being taken to begin by opening a valve 4₅ situated at the bottom of the same compartment 4 so as to allow sea water to penetrate therein as the buoyancy fluid rises to the surface.

5 After the buoyancy compartments 4 have been emptied of their buoyancy fluid, the top valves 4₄ at least are closed and the sarcophagus then presents its maximum weight which provides it with a high degree of stability, even in the event of large amounts of leakage from the
10 wreck. The effluent escaping from the wreck via said leakage collects in the top portion of the internal volume of the sarcophagus, thereby creating significant buoyancy, however this buoyancy is much less than that of the fluid that was in the compartment 4, which is
15 generally gas oil presenting relative density of 0.85. With highly viscous crude oils, relative density is generally greater than 0.95 and is often close to 1.02, thereby creating little buoyancy and running no risk of destabilizing the sarcophagus.

20 After the buoyancy compartments 4 have been emptied, the chains may be recovered, however if it is preferred to improve the stability of the sarcophagus, it is advantageous to raise the chains 13 so that their opposite ends are also carried by the beam already
25 carrying their first ends, or else they are raised and merely placed on top of the sarcophagus, so that their entire weight contributes to stabilizing said sarcophagus.

By increasing the distance between the double walls defining the compartments 4, and by using light metals,
30 e.g. aluminum for the structure, it is possible advantageously to replace gas oil with fresh water as the buoyancy fluid.

The relative density of sea water is about 1.026 at the surface and about 1.045 at a depth of 4000 m and at
35 3°C, whereas the relative density of fresh water is 1 at the surface and 1.016 at a depth of about 4000 m and a temperature of 3°C, so the buoyancy provided by fresh

water per cubic meter (m^3) thus lies in the range 26 kilograms force (kgf) at the surface and 29 kgf at a depth of 4000 m. The total volume of the compartments 4 in the following example enable the dead weight of the sarcophagus structure described below to be balanced. A sarcophagus having aluminum walls, a length of 180 m, a width of 40 m, and a height of 35 m, with a distance of 3 m between its inner and outer double walls represents a mass of aluminum equal to 3000 (metric) tonnes (T), i.e. an apparent weight in sea water of 1850 tonnes. The total volume of the compartments is $73,125 \text{ m}^3$, giving a buoyancy of 1480 tonnes when filled to 75% with fresh water. Additional buoyancy of 470 tonnes is applied in the form of floats distributed along the structure, and the stabilizing chains for lowering purposes are constituted by four identical lengths of chain each weighing 50 tonnes, each of them being installed at a corner of the sarcophagus.

For a sarcophagus having the same dimensions and made of steel, it is necessary to use a fluid of lower density than fresh water, e.g. gas oil, and the total volume of the buoyancy compartments requires the distance between the inner and outer walls to be 2.5 m. The sarcophagus then presents a mass of 7500 tonnes, i.e. an apparent weight in sea water of 6300 tonnes. The total volume of the compartments is $60,200 \text{ m}^3$, giving buoyancy of 6320 tonnes when filled to 70% with a fluid presenting relative density of 0.85, e.g. gas oil. The additional floats (280T) and the stabilizing chains (50T \times 4) remain the same as for the aluminum sarcophagus.

In an advantageous variant shown in Figures 5 and 6, it is advantageous to install a horizontal diaphragm or web 21 that is tensioned between the side walls 2, 2a, 2b, and 2₁ in such a manner as to isolate the top portion of the inside volume of the sarcophagus, which top portion is advantageously filled with fresh water. This generates additional buoyancy, thereby contributing to

the buoyancy of the sarcophagus as a whole, and making it possible to reduce correspondingly the volume of the main buoyancy fluid such as gas oil that is used for filling the internal compartments 4 within the structure of the sarcophagus. By way of example, for the two cases described above, a diaphragm situated at half height serves to confine 126,000 m³ of fresh water, thereby contributing overall buoyancy of 3400 tonnes and enabling the buoyancy compartments to be reduced correspondingly, particularly if the structure is made of steel, thus correspondingly reducing the volume of gas oil. In addition, in those zones of the structure that do not have buoyancy compartments, it becomes possible to simplify the structure, thereby reducing its weight by locally omitting one of its walls, preferably the inner wall. This diaphragm 21 is secured mechanically to the walls, e.g. by means of straps. There is no need for the connection to be entirely leaktight, since the role of the diaphragm 21 is mainly to ensure that stirring created by the current during towing to the site does not cause the fresh water to mix with sea water, which would lead to a large fraction of said fresh water being lost quickly by being dispersed in the sea water, thereby losing a large portion of the buoyancy of the structure as a whole. Once the sarcophagus 1 has been lowered to the immediate vicinity of the wreck 6, and prior to it being placed on the sea bed, the diaphragm 21 is removed, either by means of the ROV 22, or by using automatic release systems of the hydraulic actuator or explosive bolt type, and then the sarcophagus is lowered into its final position on the wreck. At the end of installation, a top drainage orifice 9 through the roof of the sarcophagus is advantageously opened so that the fresh water can escape and the stability of the sarcophagus can be improved. After the fresh water has been exhausted, said top orifice 9 is closed so as to recover any leakage coming from the wreck.

The same top orifice 9 is advantageously used for recovering the effluent 9 that escapes from the wreck 6 over time, which effluent collects in the top of the inside volume of the sarcophagus underneath its roof 3, 3a, 3b. By making a connection with this top orifice 9 and after opening the isolating valve, the oil 8 that has accumulated since the preceding campaign is advantageously transferred either by means of a pipe 23 connecting the top orifice 9 to a recovery ship situated on the surface, or else by using a recovery device between the sarcophagus and the surface ship, e.g. a device of the kind described in French patent application No. FR 2 804 935, or indeed a shuttle type device as described in yet-to-be-published European patent application No. 03/358003.6.

In a version of the invention shown in Figure 7, a hangar type load-carrying structure is made built up from beams of steel or other metal 24 assembled together by welding or bolting, and leaktight compartments are incorporated therein, being distributed continuously or otherwise, either on the side walls 2, 2a, 2b or in the roof 3, 3a, 3b, or in both of them. The structure as a whole is made leaktight against a fluid that tends naturally to escape upwards by means of diaphragms or webs 25 fixed outside the structure and against it in leaktight manner, so as to recover all leakage from the wreck and direct it towards a high point where it can be stored while waiting to be recovered, either by means of a bottom-to-surface connection 23 or by means of a recovery device or shuttle as mentioned above.

In a version of the invention shown in Figure 8, the sarcophagus structure is made of lightweight concrete 26 that is reinforced and prestressed, and it contains compartments 4 which are filled in the same manner as before with a fluid of density lower than that of sea water. The concrete 26 is advantageously made using lightweight aggregate, such as expanded clays for example,

associated with high-strength mortars, thus giving excellent behavior at great depth, even at depths of 3000 m to 4000 m, or even more. Expanded clays are substantially spherical in shape leaving gaps that are filled with air or gas, thus giving them very low density; when taken within a matrix constituted by high strength mortar, it is the matrix proper which provides overall strength. When the structure is subjected to very high pressures, e.g. the pressure of 400 bars that exists at a depth of about 4000 m, water will migrate over time into the mass of concrete and will, little by little, invade the expanded clay aggregate, thereby considerably increasing the apparent weight of the sarcophagus. Since this migration process is relatively slow it is not a disadvantage during installation since after being towed to the site, the critical operation of lowering said sarcophagus from the surface to its final position resting on the sea bed over the wreck will occupy a maximum duration of 12 hours (h) to 24 h. Once in place, the dead weight of the sarcophagus increases day by day, thereby increasing its stability, with the water migration phenomenon continuing over a period of several weeks or even several months. In order to retard water migration phenomena into the porous aggregate, it is advantageous to cover the walls of the concrete structure that come into contact with water completely in a layer of elastomer type paint, thereby creating an effective sealing barrier. This layer is advantageously also applied to the inside of the buoyancy compartments integrated in the concrete structure in order to minimize migration of buoyancy fluid into said aggregate.

It is advantageous to use a fluid of very low density, thus reducing the overall volume of the buoyancy compartments. For this purpose, it is advantageous to use butane, propane, ammonia, or any other similar gaseous compound whose relative density in the liquid state lies in the range 0.55 to 0.70. These compounds

are gaseous at atmospheric pressure and at a temperature of 20°C, but they liquefy once they have been compressed to a few bars. It is thus highly advantageous to use them as buoyancy fluid since their efficiency (in terms of buoyancy per m³ of fluid) is much more advantageous than that of gas oil or fresh water, however the compartments then need to be filled in a particular manner in order to avoid any risk of accidents or difficulties.

For this purpose, the procedure is as follows. After the sarcophagus has been built and taken out of the open basin, its compartments 4 still being empty, the compartments are filled with sea water and the assembly is made buoyant by means of barges 27, preferably two or four barges floating on the surface as shown in Figure 9a.

The sarcophagus is connected to each of said barges 27 by a cable 28 connected to a winch 28₁, in association with a pounding compensator 29 seeking to ensure that the cable 28 does not break. The assembly is then towed to the site, and then as shown in Figure 9b, the sarcophagus is lowered to a depth of 30 m to 60 m which corresponds to a pressure of 3 bars to 6 bars, at which pressure the gas that is to be injected into the compartments 4 is in liquid form. A pipe 23 is then lowered and connected to the high point 4₄ of the buoyancy compartments and liquid gas stored on board a specialized gas tanker ship 31 (known to the person skilled in the art), is injected under pressure. The bottom orifice 4₅ of the compartment is left open so the liquid gas expels the sea water therein and fills the compartment 4 completely, little by little. At the end of filling, the top valve 4₄ is closed in leaktight manner. Once all of the compartments have been filled, the barges 27 used during towing can be released after the retaining cables 28 have been disconnected. The sarcophagus can then be lowered as explained above. In Figure 9b, the right-hand compartment is full of gas in the liquid state, whereas

the left-hand compartment is being filled, with sea water escaping through the bottom valve 4₅ which is in the open position.

At the end of installation, it can suffice to open
5 the top orifice 4₄ situated at the top of each of the buoyancy compartments to a small extent so as to allow the gas to escape in liquid form: it then rises naturally towards the surface, initially in liquid form and finally in the form of gas close to the surface where it becomes
10 diluted in the atmosphere. These gases are not dangerous for the environment or for personnel, insofar as the instantaneous quantities thereof remain reasonable, i.e. constituting a few tens or a few hundreds of kilograms per hour, but it is nevertheless preferable to recover
15 the cargo of liquefied gas. For this purpose, a bottom-to-surface connection 23 is installed as described above with reference to Figure 2, which connection connects the top orifice 4₄ of each compartment to the gas tanker ship and enables nearly all of the gas cargo to be recovered
20 in a very short length of time since the gas in liquid form is very fluid and the pressure difference between the sea bed and the surface is very high, particularly when the wreck is at a depth of 3000 m to 4000 m.

In each of the variants of the invention described
25 above, the leaktight compartments are positioned and dimensioned in such a manner as to comply with the rules applicable to ship-building, and in particular with the ρ -a rule which consists in ensuring that the center of vertical thrust due to buoyancy remains above the center
30 of gravity of the structure. It is common practice to consider that for a value of ρ -a > 1 m, the structure can be considered as being stable and not in danger of turning over by pivoting about its axis XX'. For this purpose, it is advantageous to add external floats 19
35 which are preferably situated above the structure of the sarcophagus, and possibly also to ballast its bottom portions.

In each of the variants of the invention, a structure is described which covers the wreck completely down to the sea bed, however it would remain within the spirit of the invention to make use of a structure that remains at a distance of a few meters from the sea bed, standing on posts constituted by posts provided at their bottom ends with support plates, so as to limit penetration into the sea bed. This disposition makes it possible, advantageously to access the wreck under the sarcophagus by means of an ROV 22 in order to inspect it or indeed in order to operate valves, drill holes to release crude oil for recovery purposes, or indeed to place destructive explosives in order to create localized openings in the wreck.

Thus, in a preferred version of the invention as shown in Figure 10, the sarcophagus is provided at each of its corners with a post 40 having a support plate 40₁ so that the structure does not rest directly on the sea bed but stands above it, e.g. by 2 m, thereby leaving access around its entire periphery for the ROV 22 to perform inspection and other operations. Given the considerable dimensions of the structure, it is advantageous to install intermediate posts 41 along each of its faces, with said posts then being in a high, retracted position 41a during transport and lowering of the sarcophagus. Thus, once the sarcophagus has been lowered onto the wreck and is resting on the sea bed, it initially stands only on the corner posts 40, thereby conferring quasi-isostatic trim thereto. At this stage, with buoyancy still being at a maximum in the buoyancy compartments and the additional floats, the apparent weight of the structure is small and can be supported by the structure. The ROV then acts on each of the posts to operate bolts 42 for releasing the posts so that under their own weight they move away from the high, retracted position 41a into the low, deployed position 41b. Thereafter, the ROV again actuates the bolts 42 so as to

lock said posts relative to the structure of the sarcophagus. By acting in this way one each of the posts so as to cause them to go from the retracted position to the deployed position, and by locking them in the
5 deployed position, the trim of the sarcophagus structure is greatly improved, and this applies regardless of the nature of the sea bed and any obstacles that might be present beneath each of the posts. This ensures that none of the posts are left hanging while others have too
10 great a fraction of the overall load concentrated thereon, running the risk of leading to significant damage or even total loss of the structure. This disposition thus makes it possible to have quasi-isostatic trim over the entire surface via a large number of posts, and to achieve this
15 regardless of the nature of the sea bed and any obstacles that might be encountered. Once all of the posts have been deployed, it is possible to empty the buoyancy material from the buoyancy compartments so that the structure then presents its maximum weight and rests
20 safely on the sea bed even if the sea bed itself is highly non-uniform.

The buoyancy compartments are described above as having a top orifice and a bottom orifice each fitted with an isolating valve, however it would remain within
25 the spirit of the invention if the compartments were to be open-based, with the buoyancy fluid remaining in place solely because of its difference in density.

For buoyancy compartments having bottom orifices fitted with respective valves, it is preferable to keep
30 said valves closed while the structure is being towed to the site, however it is advantageous for them to be opened while the structure is being lowered towards the bottom so that variations in the volume of the buoyancy fluid due to ambient pressure and temperature do not give
35 rise to unacceptable deformation of the structure of said compartment, since that would run the risk of damaging the structure of the sarcophagus.

It is advantageous to fit square openings having a size of 2 m or 3 m halfway up the side walls 2, 2a, 2b, 2₁ so as to facilitate access for ROVs 22 for the operations described above. These openings are advantageously
5 closed under normal conditions by hinged flaps that are locked in place in leaktight manner so as to avoid losing any polluting substances coming from the wreck.

Figures 11a to 11d and 12 show a shuttle tank 32 of the type serving to recover effluent from a wreck on the
10 sea bed by lowering and raising said shuttle tank respectively when empty and when full, between the surface and the bed of the sea. The shuttle tank 32 is constituted by a side wall 34 that is flexible and leaktight, e.g. made of strong reinforced plasticized
15 fabric, said side wall being secured at its top portion to a dome 33 having a circular horizontal section and having a bullet-shaped profile in vertical section, and that is made of a strong and rigid material, preferably a composite material, and said side wall being secured at
20 its bottom portion to a plane, solid, strong, rigid, and preferably circular bottom wall 35, which is itself also preferably made of composite material so as to represent a minimum apparent weight in water, while guaranteeing extreme rigidity and strength. Said bottom wall 35 is
25 pierced at its center by a main orifice 35₁ and is fitted with a valve, preferably a draw-off valve, e.g. of the guillotine type, said valve being fitted with a flange. A complementary side orifice of smaller diameter is provided with a valve 35₂, thereby enabling sea water to
30 be exchanged between the inside of the shuttle tank and the marine environment, and in particular enabling sea water to escape while the tank is being filled with oil.

The dome 33 and the bottom wall 35 can present a diameter in the range 5 m to 10 m, the dome 33 can
35 present a height in the range 2 m to 5 m, and the side wall 34 can present a height in the range 10 m to 50 m, once deployed.

The apparent weight in water of the shuttle tank 32 is advantageously adjusted by integrating buoyancy into the highest portion of the dome 33, e.g. syntactic foam 33₁ constituted by microspheres of glass coated in epoxy, polyurethane, or other resins.

The shuttle tank 32 is thus lowered to the wreck or tank 6, or even to a sarcophagus 1 placed over a said wreck or tank, in the collapsed position, and presents an apparent weight in water that is very light and that can be adjusted both positively and negatively, thereby making it easy to install directly by using an ROV controlled from the surface and provided with manipulator arms.

Figure 11a shows that the raising of the shuttle tank 32 is controlled by a connection cable 12 having a fraction of its bottom portion 13 that is weighted, e.g. by metal blocks 31 secured to said cable 30 by clamping at 31₁ like a string of beads.

As shown in Figure 11d, the beads 31 have a cylindrical central body that is prismatic or circularly cylindrical, and frustoconical ends, so that when the cable is curved, the frustoconical ends of two adjacent beads thus come into abutment against each other at 31₂, thereby limiting the local radius of curvature to a value that is greater than R_0 . Thus, the connection cable 12, being fastened to the shuttle tank 32 at said first fastener point 36 at the bottom of the tank, descends, then moves away through an arc of a circle of radius R_0 , before finally rising vertically or in a catenary configuration at a distance of about at least $2R_0$ from the side wall 4 of said shuttle tank, thereby avoiding any mechanical contact during raising, and thereby preventing said connection cable from being damaged by rubbing.

In Figure 11a, the buoyancy of the shuttle tank filled with hydrocarbons F_v that corresponds to the buoyancy thrust that is exerted on the tank and its cargo is compensated by the weight of the cable up to the

horizontal tangent point corresponding to the bead 31_i , added to the weight of the beads 31_g between the tank and the lowest bead 31_i , i.e. 8.5 beads in Figure 11a, the overall weight P_e thus corresponding to the system being

5

in equilibrium.
By way of example, in order to illustrate Figure 11a, the shuttle tank having a volume of 250 m^3 of oil of density 1011 kilograms per cubic meter (kg/m^3), in sea water at 3°C of density 1045 kg/m^3 , has a buoyancy of

10

about 8.5 tonnes.
Each of the beads of the equilibrium device 30-31 thus has a weight in water of about 1 tonne.

In Figure 11b, the top end of the connection cable 12 connected to a winch installed on board a surface ship (not shown) is raised, thereby bringing the bead 31_g in Figure 11 into the bottom horizontal position, and thereby reducing the number of beads hanging from the tank to 6.5 beads, the overall weight opposing the F_v thrust thus being reduced to P_- . The resultant $F_v + P_-$ is thus upwardly positive and the shuttle tank can rise until the force equilibrium of Figure 11a is reached.

15

20

In addition, in Figure 11c, the top end of the connection cable 12 is veered (lowered), thereby bringing the bead 31_k into the bottom horizontal position, and thereby increasing the number of beads hanging from the tank to 10.5 beads, with the overall weight thus being equal to P_+ . The resultant $F_v + P_+$ is thus downwardly positive and the shuttle tank can move back down until the force equilibrium of Figure 11a is reached.

25

30

Thus, the stabilizing device of the invention presents a stabilizing effect while the shuttle tank is being raised. When the surface ship moves excessively under the effect of swell or moves away from the vertical above the position of the shuttle tank, the movements have an instantaneous effect on only the zone of the beads surrounding the beads 31_g to 31_k , the bead 31_i corresponding to the mean value of the oscillations.

35

Thus, in order to control the raising of the shuttle tank 32, it suffices to wind the connection cable onto the winch situated on board the surface ship 20 at a speed that is compatible with the natural rate of rise of said shuttle tank, with said shuttle tank naturally always seeking to return to its equilibrium position shown in Figure 11a. In the event of difficulties, it suffices to slow down or stop winding onto the winch, the shuttle tank then finding its position of equilibrium almost immediately, while waiting for the winch to restart.

Figure 12 shows a shuttle tank 32 installed in register with of an emptying device 9 fitted with a valve provided on the top wall of a sarcophagus 1 to which said shuttle tank is connected by a connection 50. When the valve is in its open position, it passes through the crude oil that has accumulated inside said sarcophagus, after flowing out from the tanks of the ship 6. It can thus be collected in the shuttle tank, which can be raised to the surface once full and once the connection 50 has been broken, with the rise to the surface being performed under the control of a device of the invention for stabilizing and controlling raising and lowering. The sarcophagus 1 is fitted with a stabilizing and control device of the invention having connection elements 12 constituted by cables, each having a bottom portion that comprises a string of metal blocks 31.

The device for controlling the lowering or raising of a heavy or massive structure is described above as being constituted either by a cable provided with blocks or beads clamped onto said cable, or by a chain having links that are modified so as to create the minimum radius of curvature R_0 merely by abutment between links. But, it is not beyond the ambit of the invention for said heavy portion of said connection elements to be constituted by a string of heavy bars that are hinged together so that deformation of the string of hinged bars

creates a load imbalance of $P+$ or $P-$ relative to the equilibrium load P_e , as described above with regard to Figures 11a, 11b and 11c, said bars advantageously presenting mechanical abutments at the hinges, making it possible to limit the curvature to a minimum value R_0 .

Figure 13 shows a heavy structure consisting of a device 1 for placing and anchoring a base 52 on the wall 54 of a tank and/or of a shipwreck on the sea bed. The device 1 comprises a support structure 54 constituted by a rectangular machine-welded stand, itself supporting:

- a drill body 54₁ comprising means for actuating a crown saw 55 both in translation and in rotation, which saw, through a corresponding opening provided in said base, enables a large orifice to be pierced in said wall 6 so as to allow fluid contained in said tank to be evacuated; and

- side carriages 56 comprising means for actuating crown saws 57 both in translation and in rotation that are capable of piercing holes in said wall 6 in order to anchor the base 52 to said wall, the crown saws 57 being displaced through orifices 58 in said base.

Figure 13 shows the lowering of a structure 1 consisting of an anchoring and piercing device controlled by a stabilizing chain 12, 13 of the invention, and by a buoyancy element 19. The bottom lefthand portion of the base 52 is shown in section in order to show the cutting means 57 inside an orifice 58 provided in said base.

The device 1 is suspended by a connection 59 from a buoyancy element 19. A connection element 12 of the cable type, having a bottom portion 13 comprising weighting blocks 31 disposed in a string as mentioned above, and extending from a surface-floating support to a fastener element 36 at the base of a buoyancy element 19, makes it possible to control the speed at which the device 1 is lowered and raised, and where appropriate, makes it possible to stabilize it in the vicinity of the wall 6, in accordance with the present invention.